

2011 Al Seiff Award Lecture

The Huygens Story

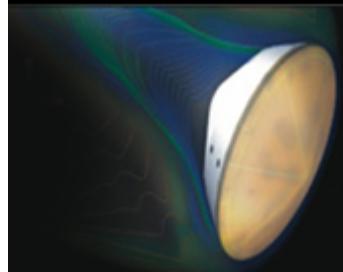
Jean-Pierre Lebreton (1,2)

(1) ESA/ESTEC, RSSD, Noordwijk, Netherlands, , jean-pierre.lebreton@esa.int

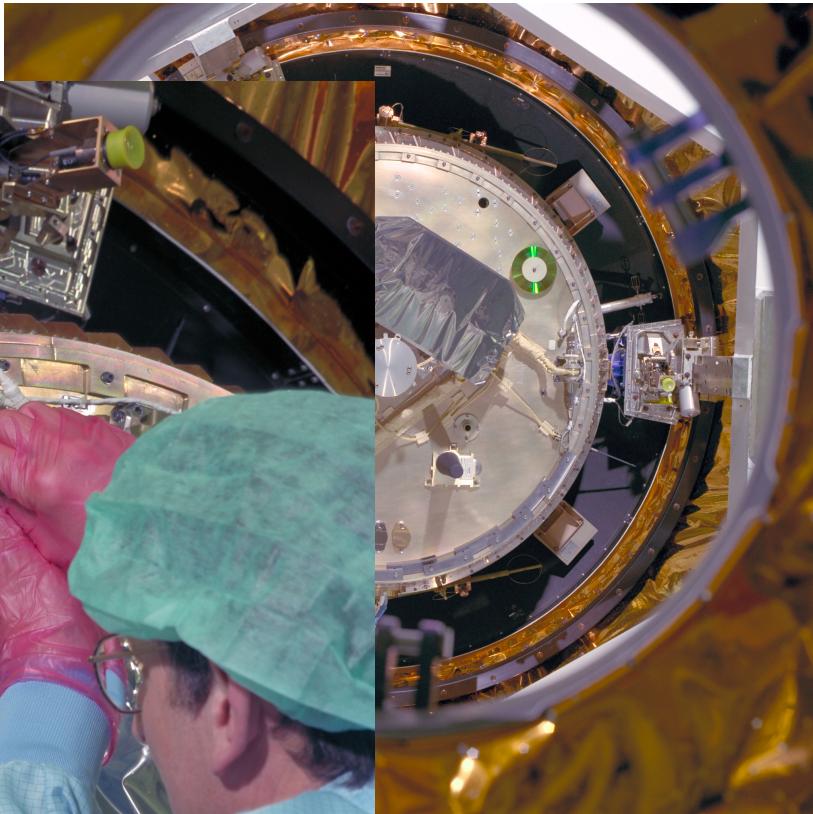
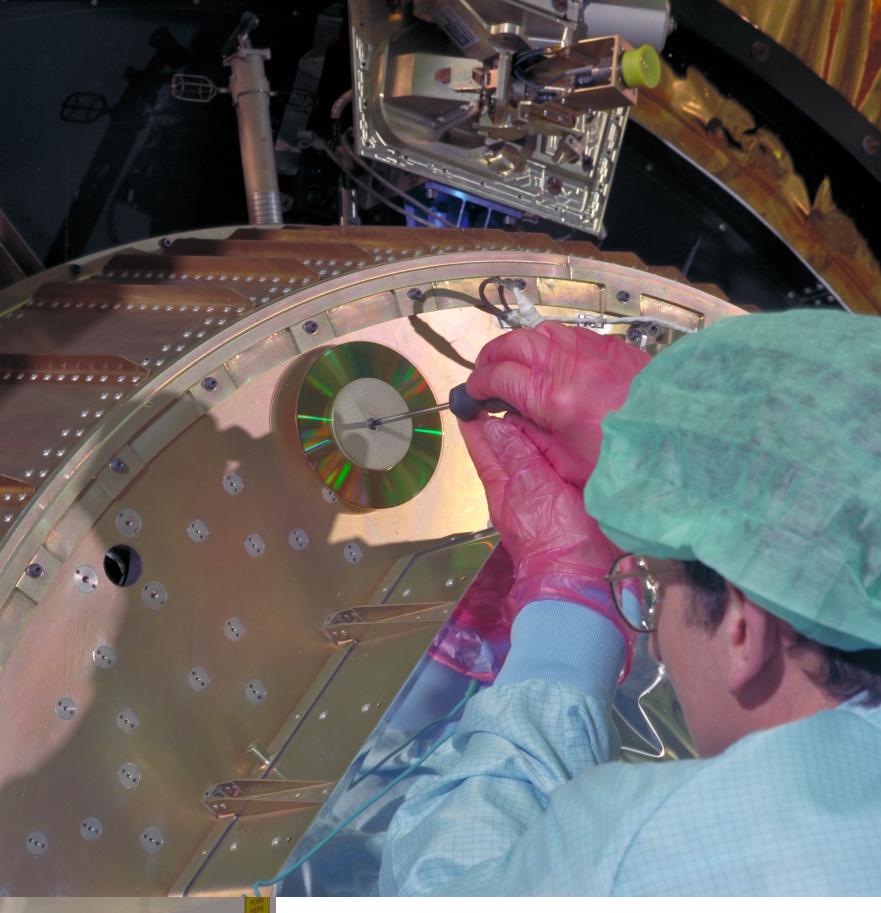
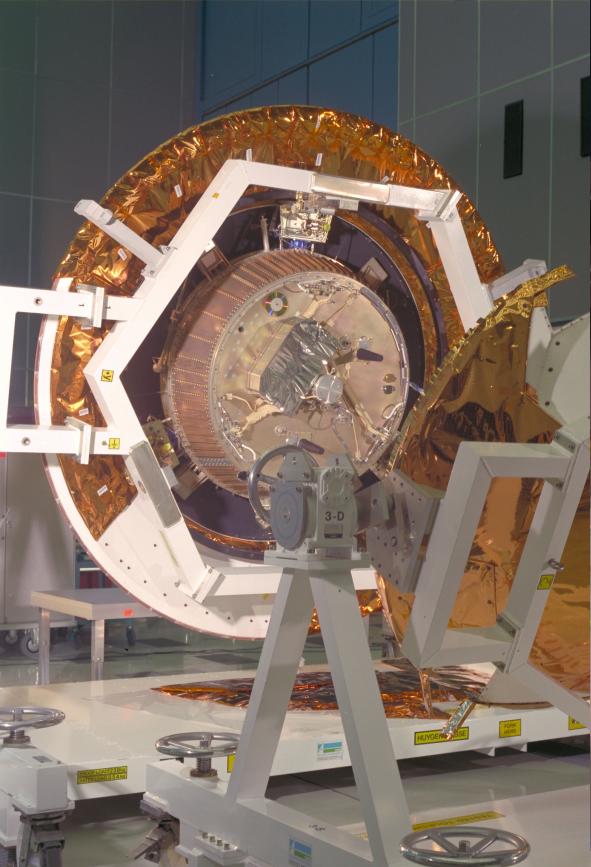
(2) CNRS/LPC2E, Orleans, France, jean-pierre.lebreton@cnrs-orleans.fr



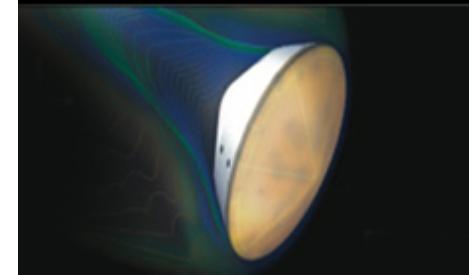
Al Seiff Involvement in Huygens



- HASI Co-Investigator

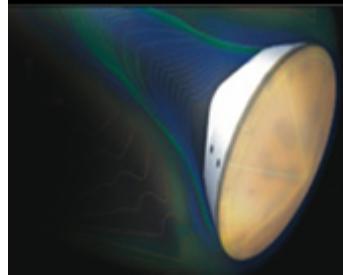


Special thanks



- Ralph Lorenz, (YGT's Huygens Project Team, 2001-2002)
- Stephan Ott (YGT's Huygens Project Team, 2001-2002); Mission analysis, ISO, Herschel
- Francesca Ferri :RF 1998-2000;Titan & Mars science, HASI Team, Netlanders, Exomars
- Roland Trautner (1999-2011), Huygens instrumentation, HASI team, Exomars
- Olivier Witasse (RF:2000-2002, Deputy PS 2003-2006), science support, Ground-based observation coordination, Data archive; Mars Express, Exomars/TGO
- Daniel Firre (Stagiaire 2001); HRTF; ESOC
- Bobby Kazeminejad (2001-2005); HRTF and DTWG; Galileo Project
- Miguel Perez (2002-2005), Sci Ops support, Venus Express Science Operations Team
- Alexandre Piot (RF: 2003-2005), Radar balloon flight; ATV Team
- Sandrine Maloreau (Stagiaire 2003); Balloon radar data processing,
- Thomas Civeit (Stagiaire 2003); Titan winds observation; SOFIA Science Operations Team
- Elias Roussos (Stagiaire 2004), Huygens mission scenario simu; Cassini MIMI Team
- Alain Sarlette (Stagiaire 2005); Comparative studies Huygens Drop-test & Huygens spin;
- Arnaud Magette (Stagiaire 2005); Comparative studies Earth & Titan lightning detection;

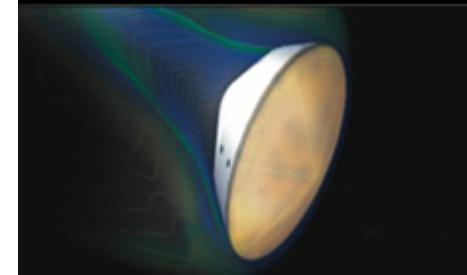
Key Cassini-Huygens dates



- Nov. 2980: Voyager Titan flyby
- 1982: Cassini Mission Proposal to ESA
- Spring 1984: Joint ESA-NASA Study started: (my first direct encounter with Titan)
- 1984-1985: Joint ESA-NASA assessment of the Cassini mission
- 1987-1988: Joint ESA-NASA of Cassini Phase A
- 1989: ESA's Selection of Titan Probe (named Huygens)
- 1990: NASA's New Start
- Ralph Lorenz joins ESA Huygens Project Team as a YGT in early 1991 (start of Phase B)
- Cassini-Huygens launch: 1997 (Huy. designed to be released on 1st Titan encounter)
- Dec. 2000 : Jupiter Flyby
- Feb. 2001 : Special in-flight cal test reveals Doppler Problem
- 2001-2004: HRTF, etc... New Cassini-Huygens Mission profile (Huy. to be released on 3rd Titan encounter)
- 20 June 2004: SOI. Cassini-Huygens is in orbit around Saturn
- 25 December 2004: Huygens release. Gone !
- 14 January 2005: Smiles and Tears
- July 2006: Huygens data set archived in ESA's PSA and mirrored in NASA's PDS
- June 2011. Cassini has explored Saturn for about a season. An other one to go !

Titan Engineering Models

(ref. to ESA SP 1177)

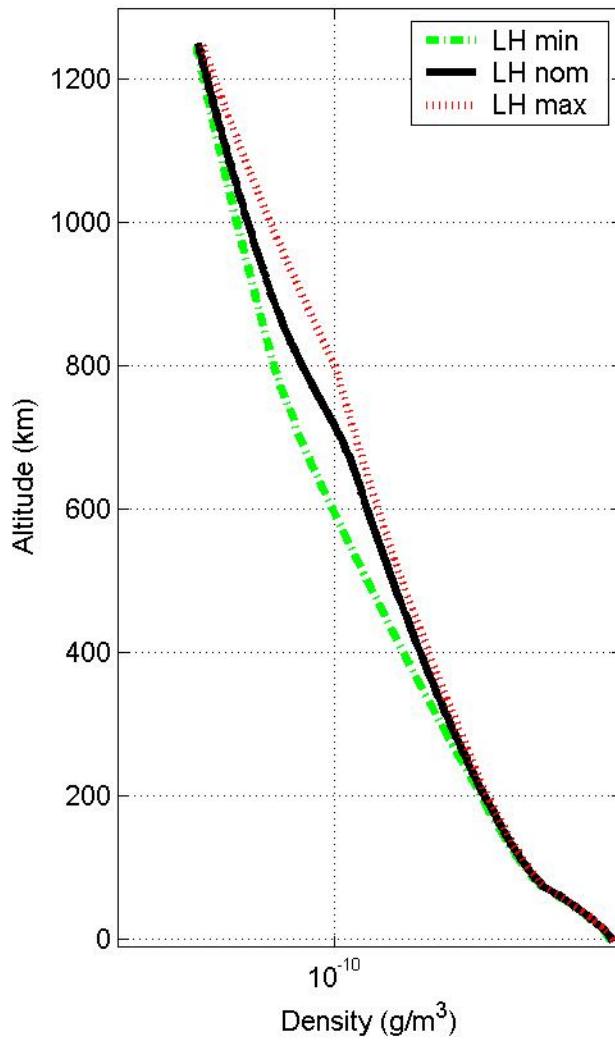


- Atmosphere Structure Models (T, ρ , composition): Entry aerothermodynamics, Parachute performances (Lellouch-Hunten, Yelle)
- Zonal wind models: Parachute deployment loads, Probe drift effects (Flasar)
- Atmospheric Gravity Waves: effects of structure gradients, turbulence (Strobel, Sicardy)
- Lightning and triboelectric charging (Lorenz)
- Moist convection model (Lunine)
- Radar reflectivities of plausible Titan surfaces (Kirk)
- Atmospheric attenuation of Radio S-band signal (Bird)

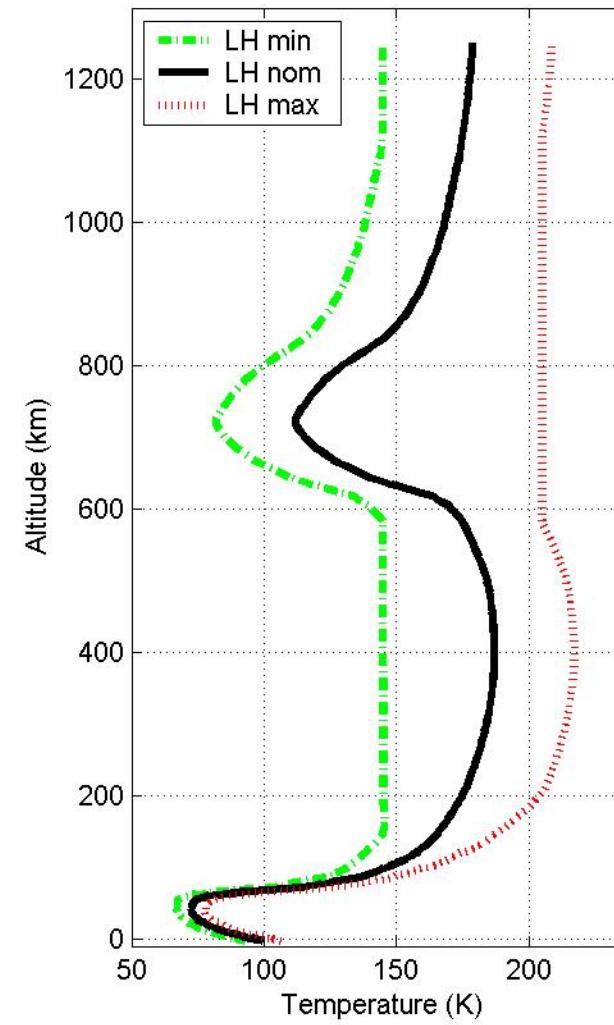
Lellouch-Hunten Model (1987)



Density Profile



Temperature Profile

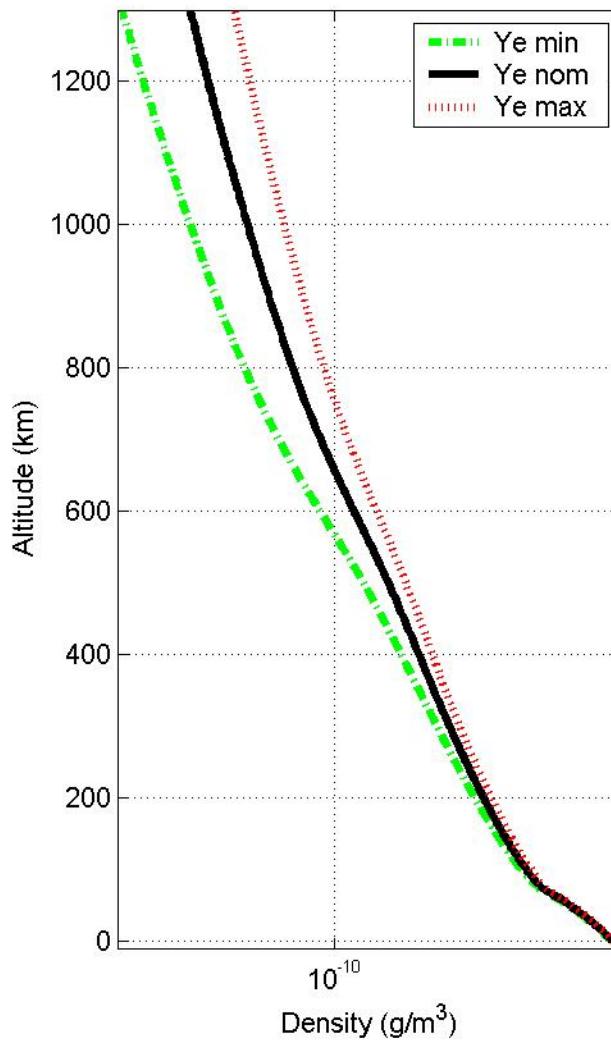


Three main components are Nitrogen (N_2), Methane (CH_4), and Argon (Ar).
 $0.5\% < X_{\text{CH}_4}/X_{\text{N}_2} < 3.5\%$; Relative molar abundance of Argon : $0 < X_{\text{Ar}}/X_{\text{N}_2} < 27\%$.

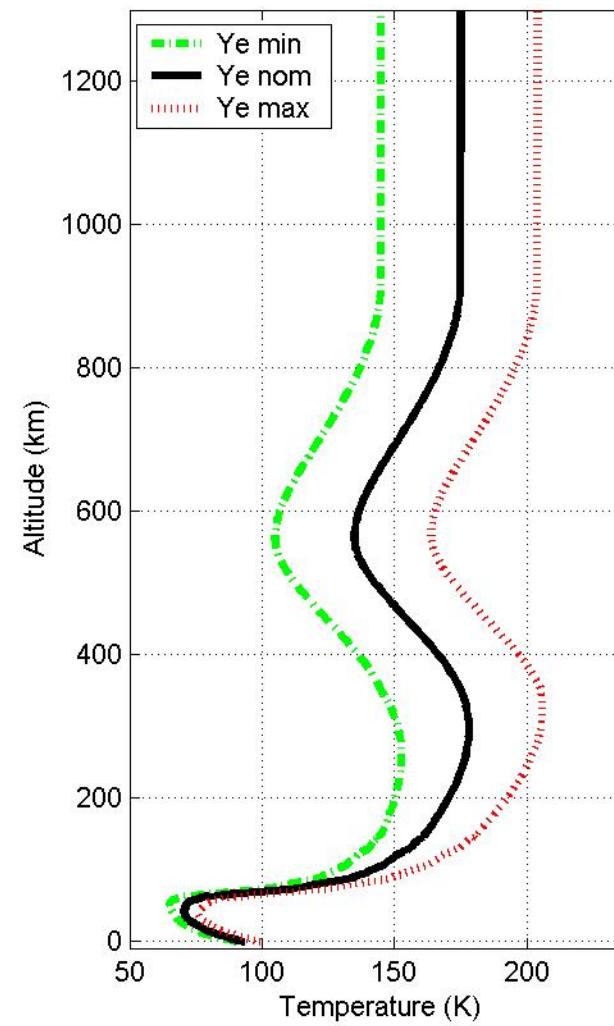
Yelle Model (1994)



Density Profile



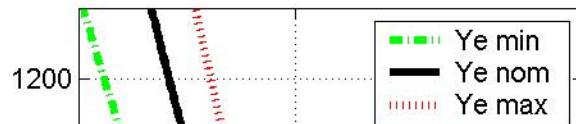
Temperature Profile



Yelle Model



Density Profile



Temperature Profile

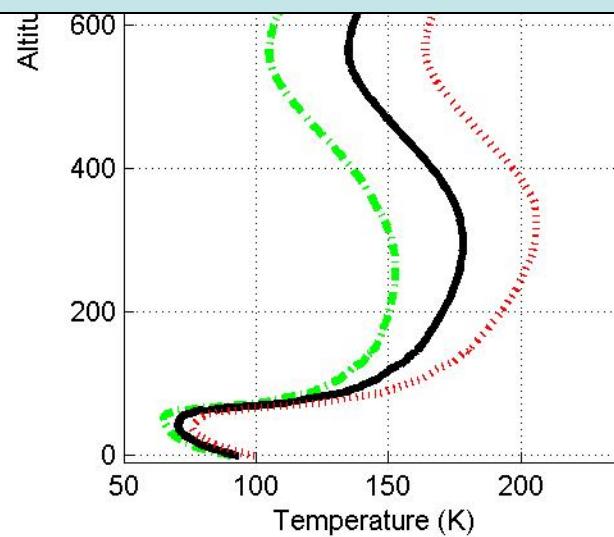
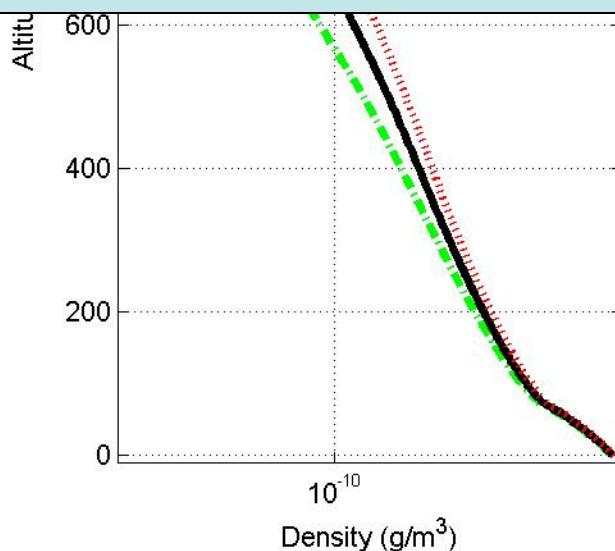


	Min	Nom	Max
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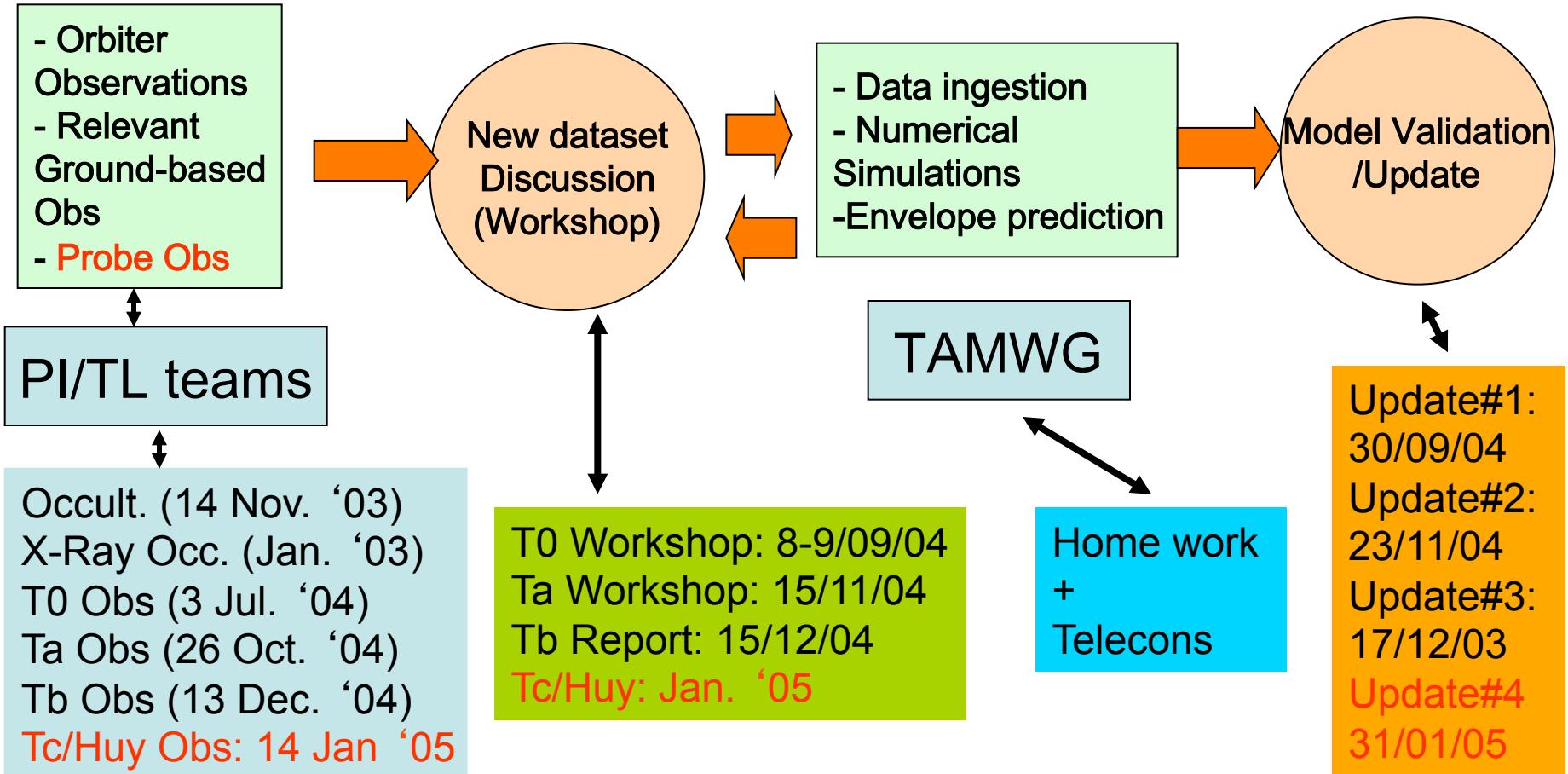
N ₂	95%	95%	89%
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CH ₄	5%	3%	1%
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Ar	0%	2%	10%
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Titan Atmosphere: From Observations to Model Validation/Update



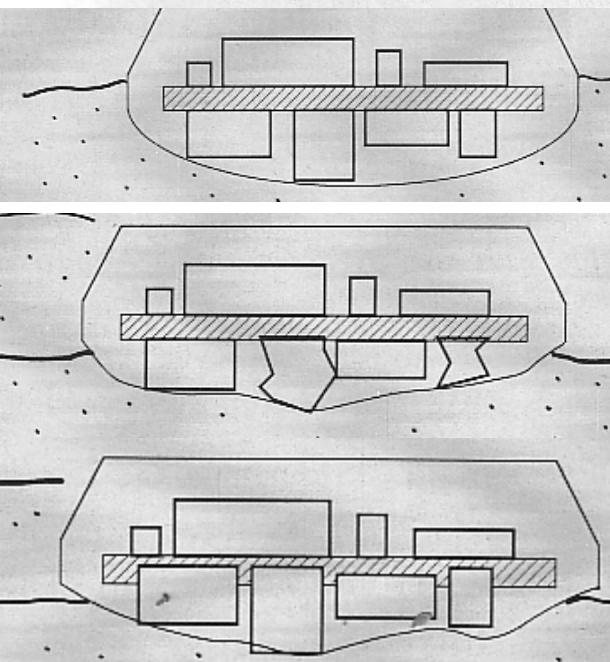
Huygens SSP EPDR, August 1991 - Ralph Lorenz, ESA Young Graduate Trainee



Huygens
encounter, ESOC,
January 2005.
SDT chair Titan
Flagship study
2007.
Project Scientist,
Titan Mare
Explorer, 2011

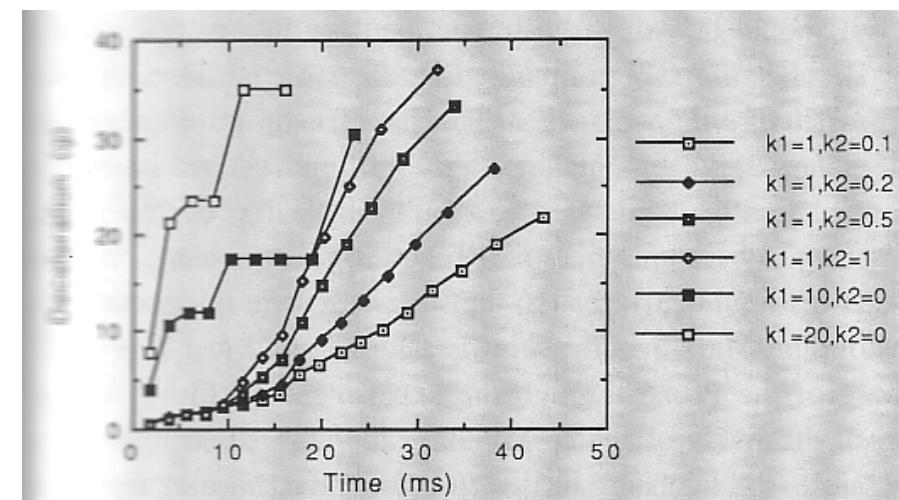
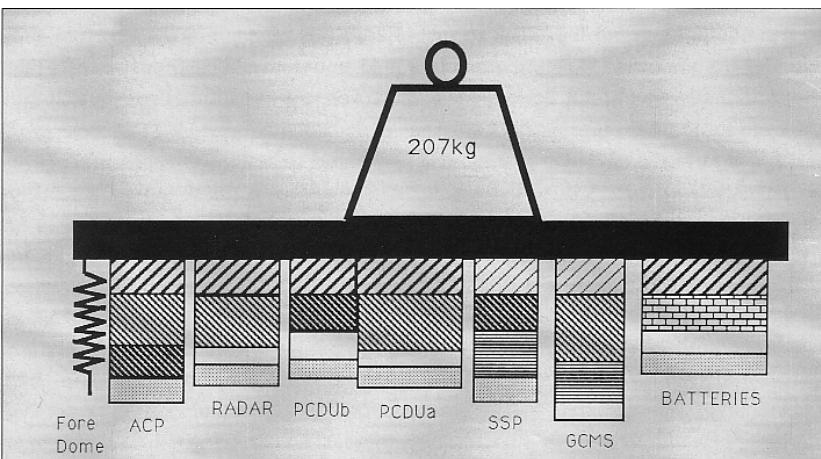


Huygens Probe Impact Dynamics

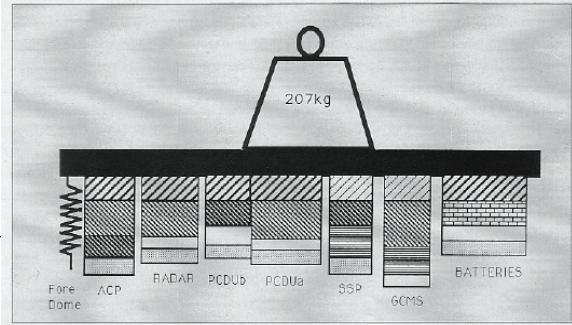


small). The Gas Chromatograph/Mass Spectrometer is a long cylindrical instrument and projects from the base of the Probe through the experiment platform. A hard impact will probably crush the inlets of the instrument, although some instrument operation may still be possible (the inlets are heated to volatilise surface material for analysis); extreme loading would punch the GCMS through the experiment platform.

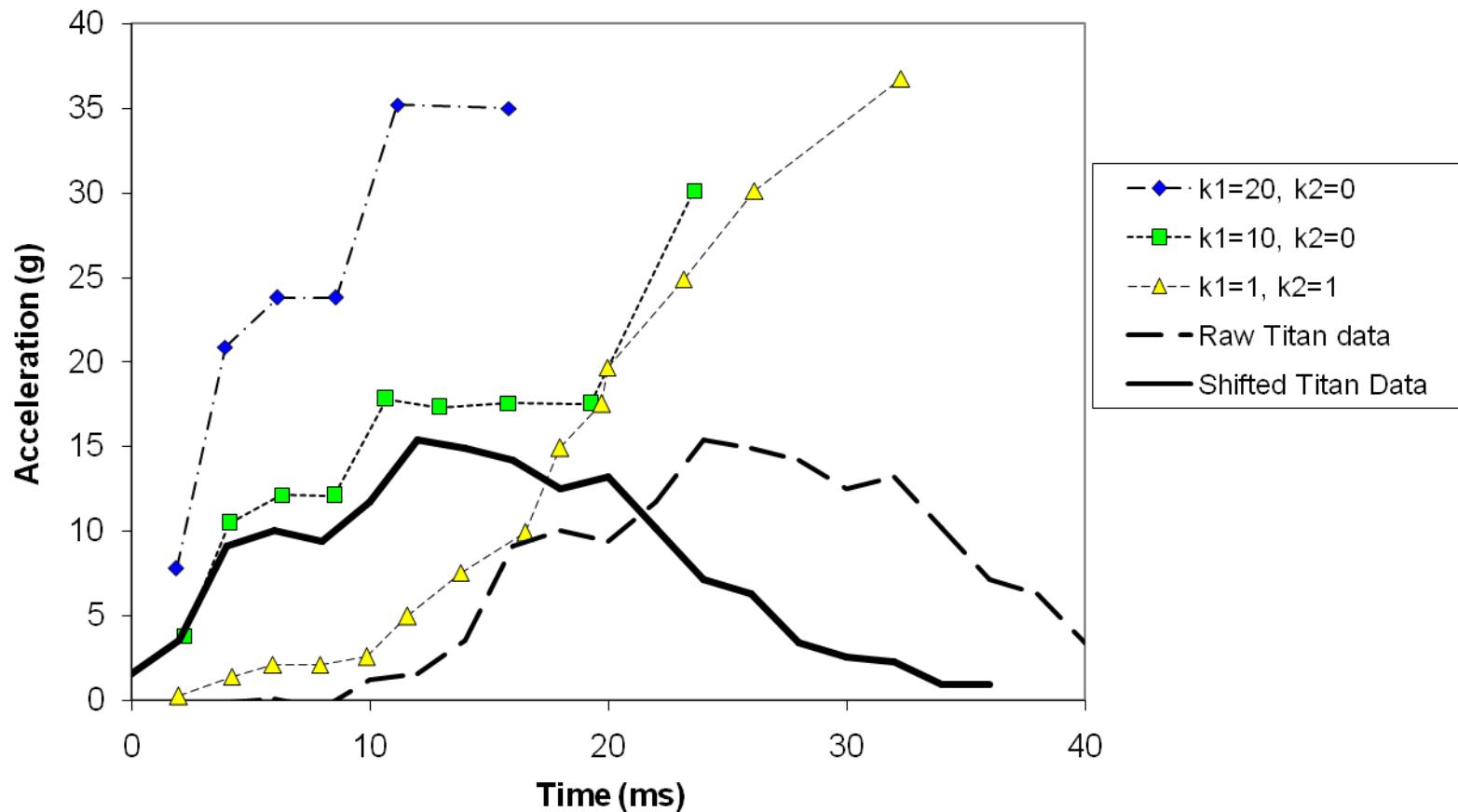
Thus a reasonable portion of the payload should remain operational after impact on a solid surface, in particular the Descent Imager/Spectral Radiometer, on the upper part of the spacecraft, which will be able to return images (using its side-looking imag
e. Additionally, upward-looking photometric sensors on the platform will be able to measure any impact-generated dust cloud (see later). A group has been set up within the Huygens Science Working Team (HSWT) to consider the measurements that are expected (or should be aimed for) post-impact.



Comparison with Lorenz (1994)
numerical model.



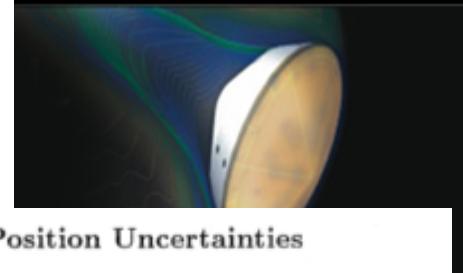
Lorenz (1994) Simulations : $P(x)=k_1+k_2x$



As noted within minutes of data receipt, overall profile is not dissimilar from $k_1=10 \text{ N/cm}^2$ model. NB model is pseudostatic penetration (no dynamical terms) – hence monotonic.

Targetting Requirements

46 *Analysis of Targeting Requirements for the Huygens Mission*



Ari

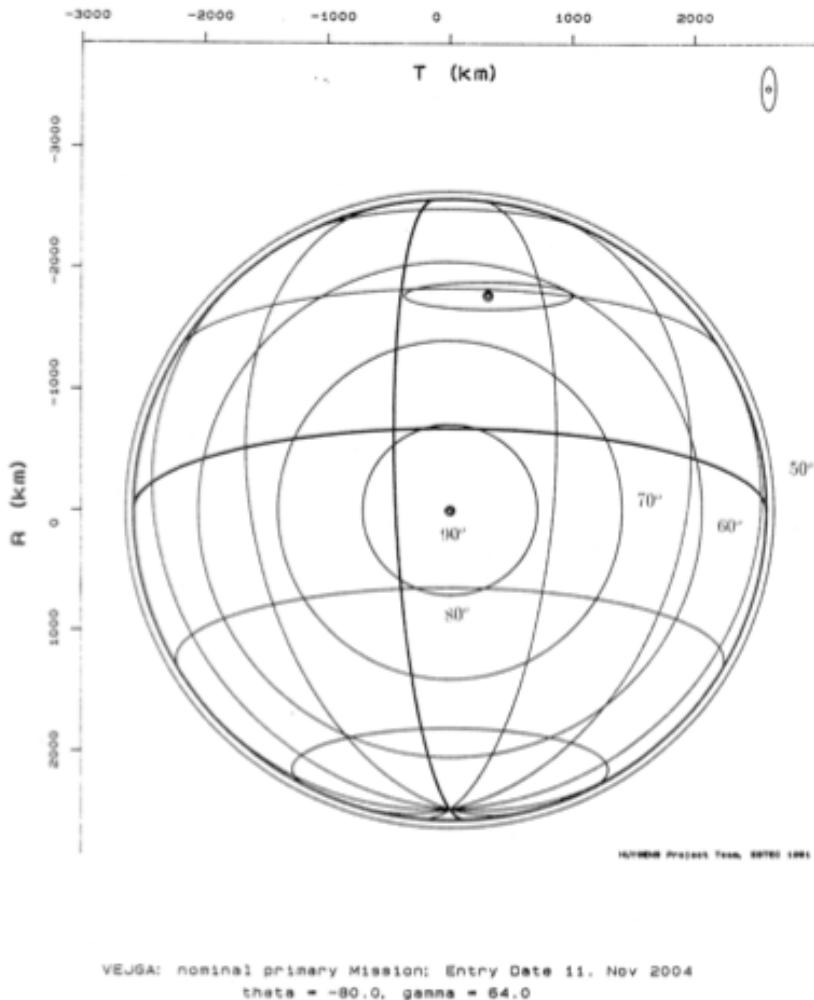


Figure 4.11: Aim Points for the PDR-Baseline

A.2 Illustration of the Position Uncertainties

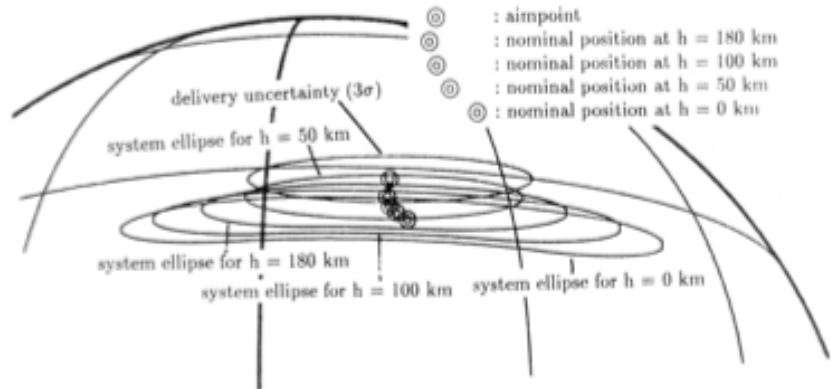


Figure A.11: Illustration of the Evolution of the System Ellipse

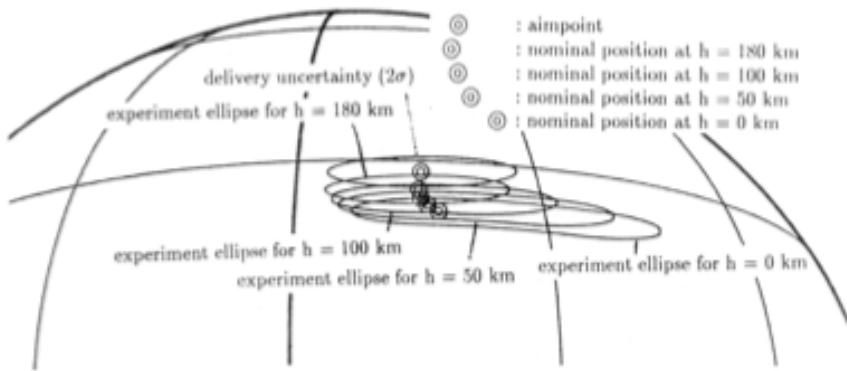
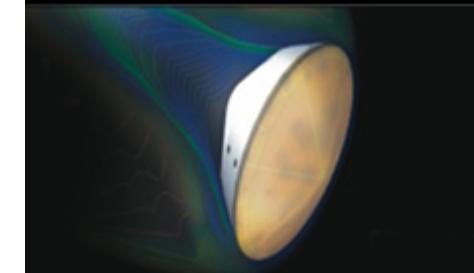


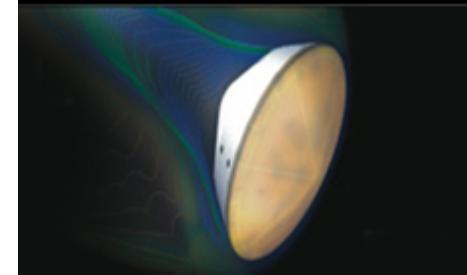
Figure A.12: Illustration of the Evolution of the Experiment Ellipse

Descent Trajectory Reconstruction: DTWG

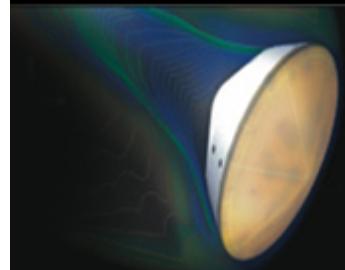
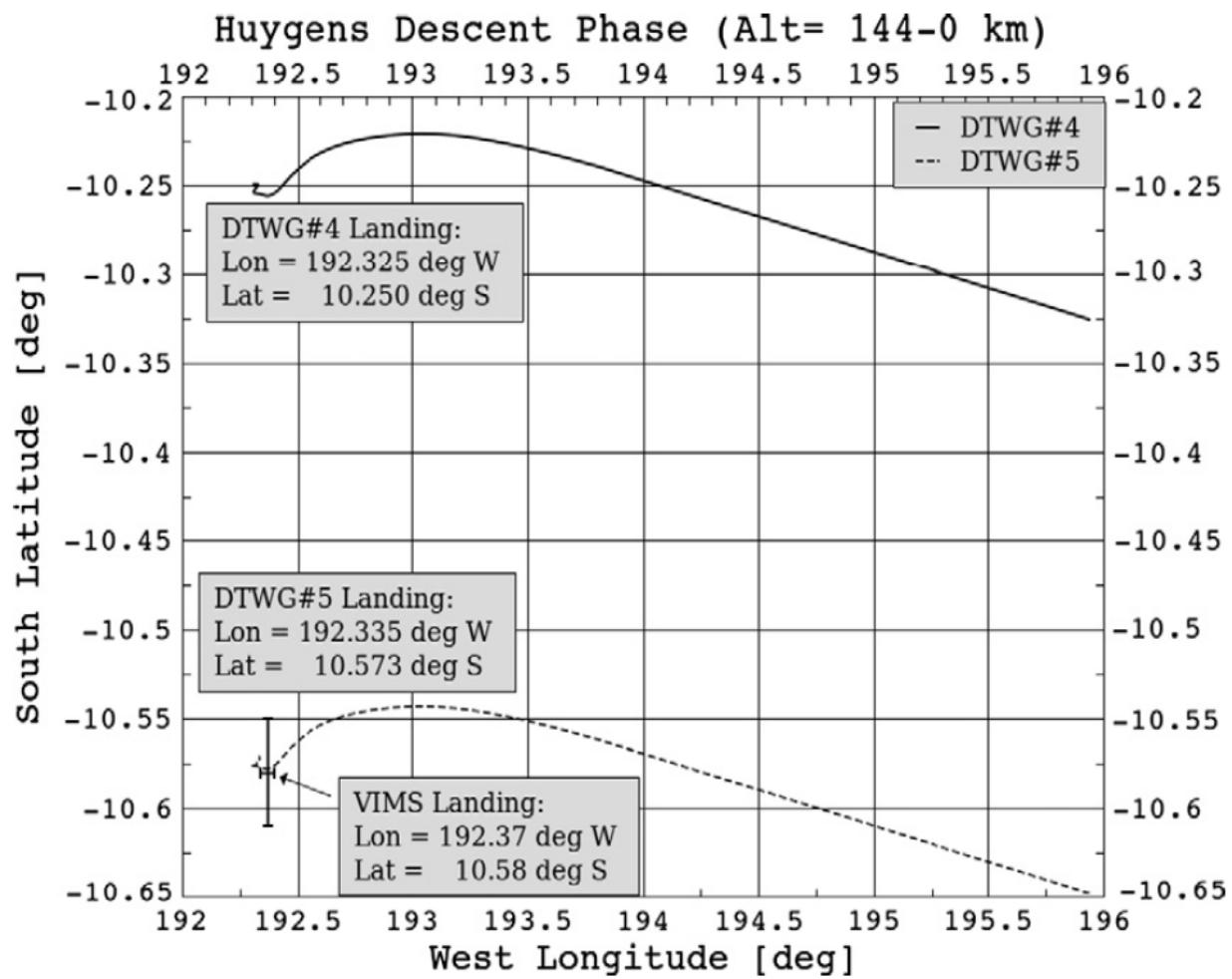


- DTWG set-up during Probe Mission development under Dave Atkinson's leadership. Galileo's experience was brought in.
- Extracts from Minutes of HSWT#15 meeting (March 1997)
 - The HSWT emphasises the usefulness of the role of the DTWG. The HSWT recommends that this body be maintained at a low level during the cruise phase and at a full level of activity after the Probe descent during the early data analysis phase.
 - It was agreed by the HSWT that a low level of activity will be maintained during the cruise phase (R. Lorenz is setting up a Web page). The need for a DTWG co-chair was discussed. No decision was taken. A co-chair will be required for the data analysis phase.
- DTWG work led to IPPW series (Lisbon, 2000)
- Great opportunity for a Young Scientist materialised

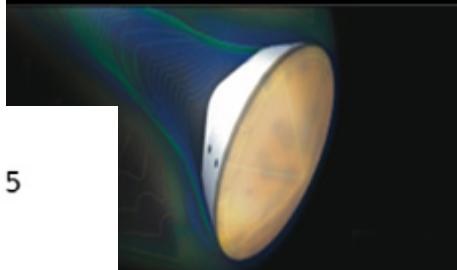
Bobby Kazeminejad



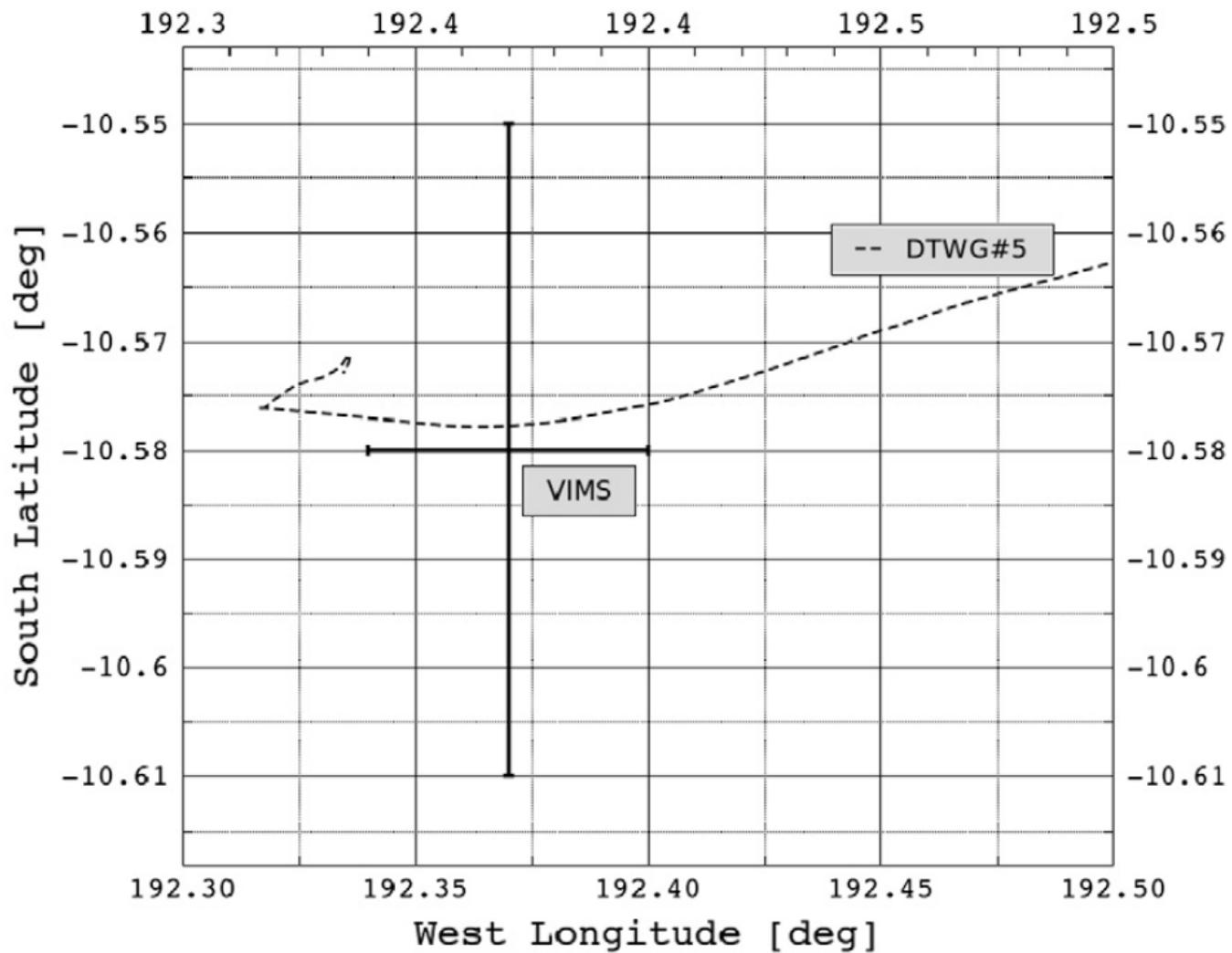
- Studies of Astronomy and Technical Physics at Technical University Graz, Austria
- Joined the Huygens Mission Team in 2001 as ESA Young Graduate Trainee at the age of 25
- Youngest member of the Huygens Recovery Task Force to define a new Cassini/ Huygens mission scenario
- Co-located at NASA JPL as member of the Huygens Mission Implementation Team
- PhD student and co-chair with Dave Atkinson of the Huygens Descent Trajectory Working Group (2002)
- DTWG Reconstruction and PI delivery of the first post-flight trajectory only 2 days after probe landing
- Publication of the official project trajectory in 2007
- Update of the official trajectory and comparison to VIMS landing coordinates in 2011



*Kazeminejad et al., Advances in Space Res., Vol 47, p1622-1632, 2011.
VIMS/DTWG#5 residuals: $\Delta\text{lon}=0.035 \text{ deg}$, $\Delta\text{lat}=0.007 \text{ deg}$*

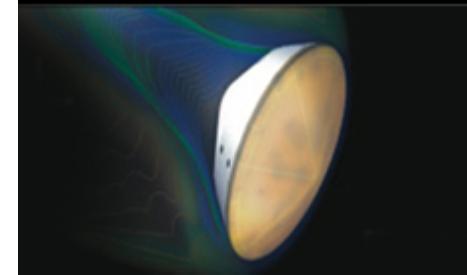


Huygens Descent Phase (Alt= 25–0 km)

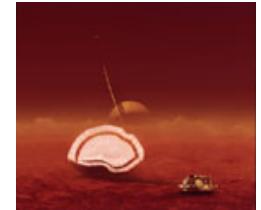


Kazeminejad et al., *Advances in Space Res.*, Vol 47, p1622-1632, 2011.
VIMS/DTWG#5 residuals: $\Delta\text{lon}=0.035 \text{ deg}$, $\Delta\text{lat}=0.007 \text{ deg}$

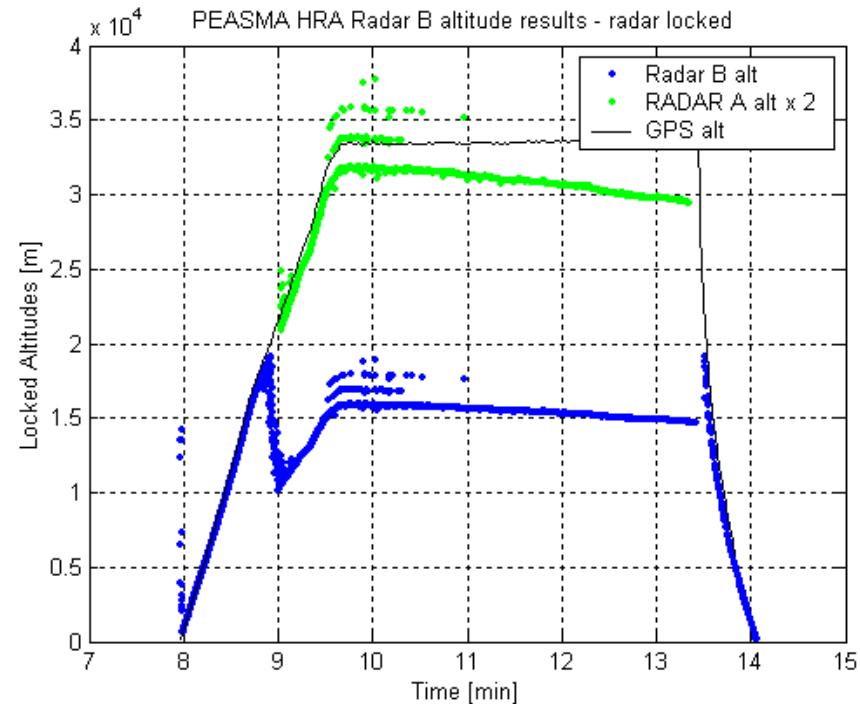
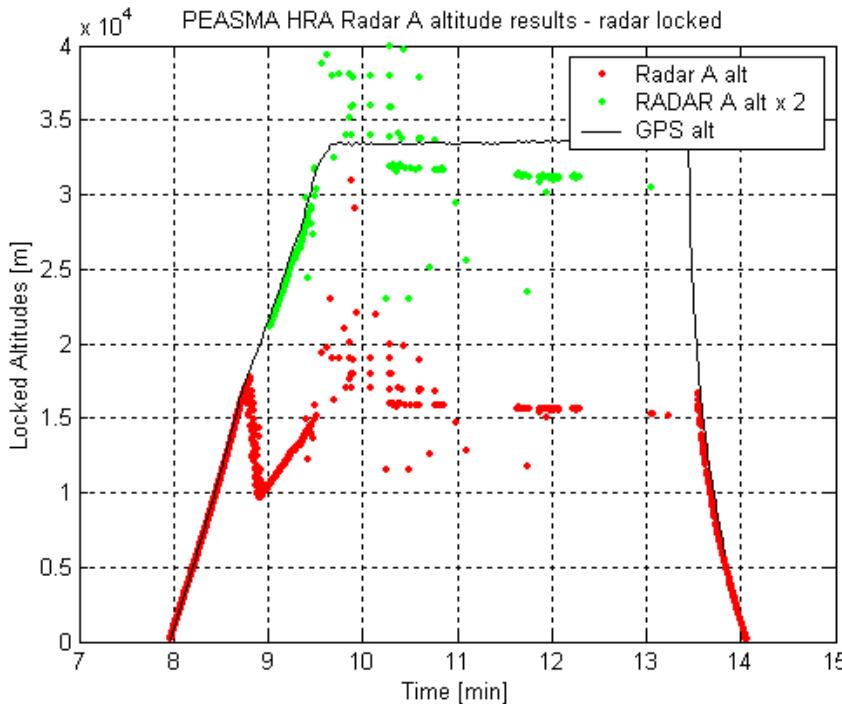
Radar Altimeter Story

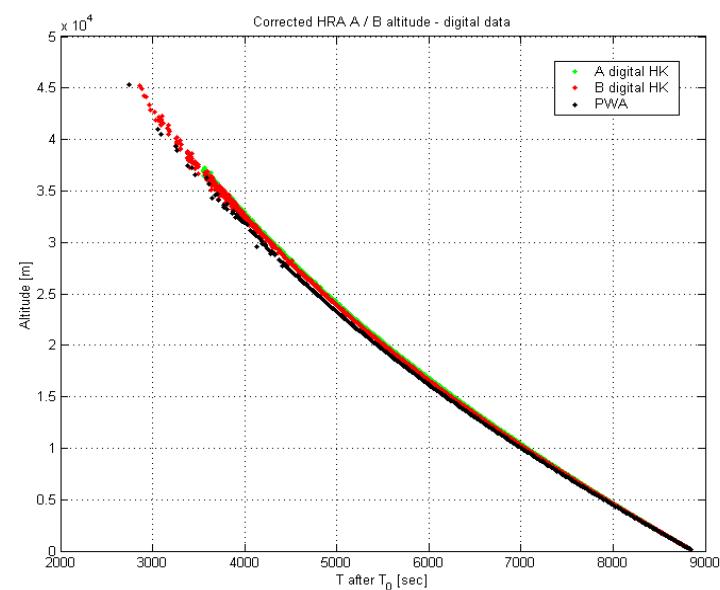
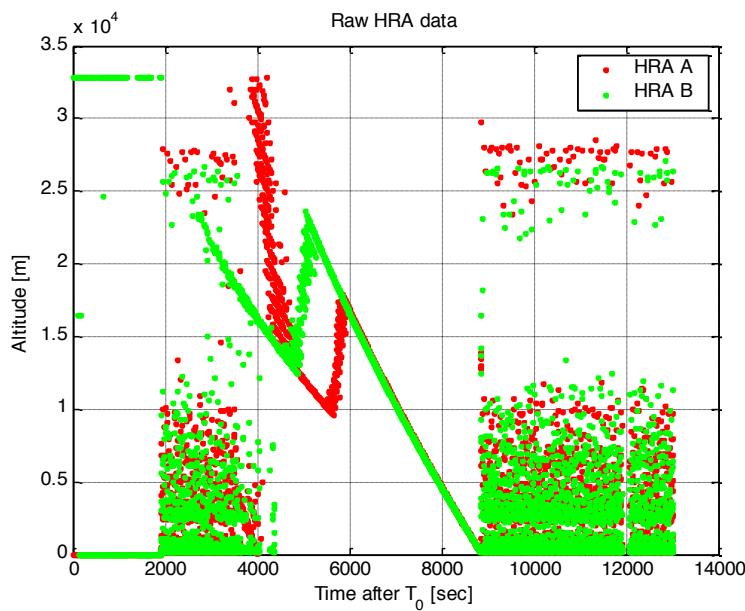
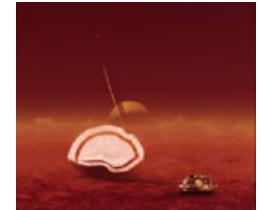


- Included as a system sensor to provide altitude to payload operational reasons (10 % accuracy specs). FMCW radio altimeter.
- Worked a project agreement to provide echo signal to HASI. HRA RADAR-HASI interface.
- Designed (and tested) for below 10 km Altitude. But switched on at 60 km.
- Provided erroneous altitude above 15 km, which was declared « true » despite a very robust algorithm. Confused DISR for a while. Recovered below 15 km.



- Digital data from HRA A / B recorded by PC DAQ shows identical behavior but at (slightly) different times and different altitudes
- MSB (bit 15) is zero at high altitude, bits 15-12 fluctuate during transient phase
- When multiplied by 2, alt reading at high altitude is correct (when temp error compensated)





Distance: 7,298.1 km

Radius: 2,575.0 km

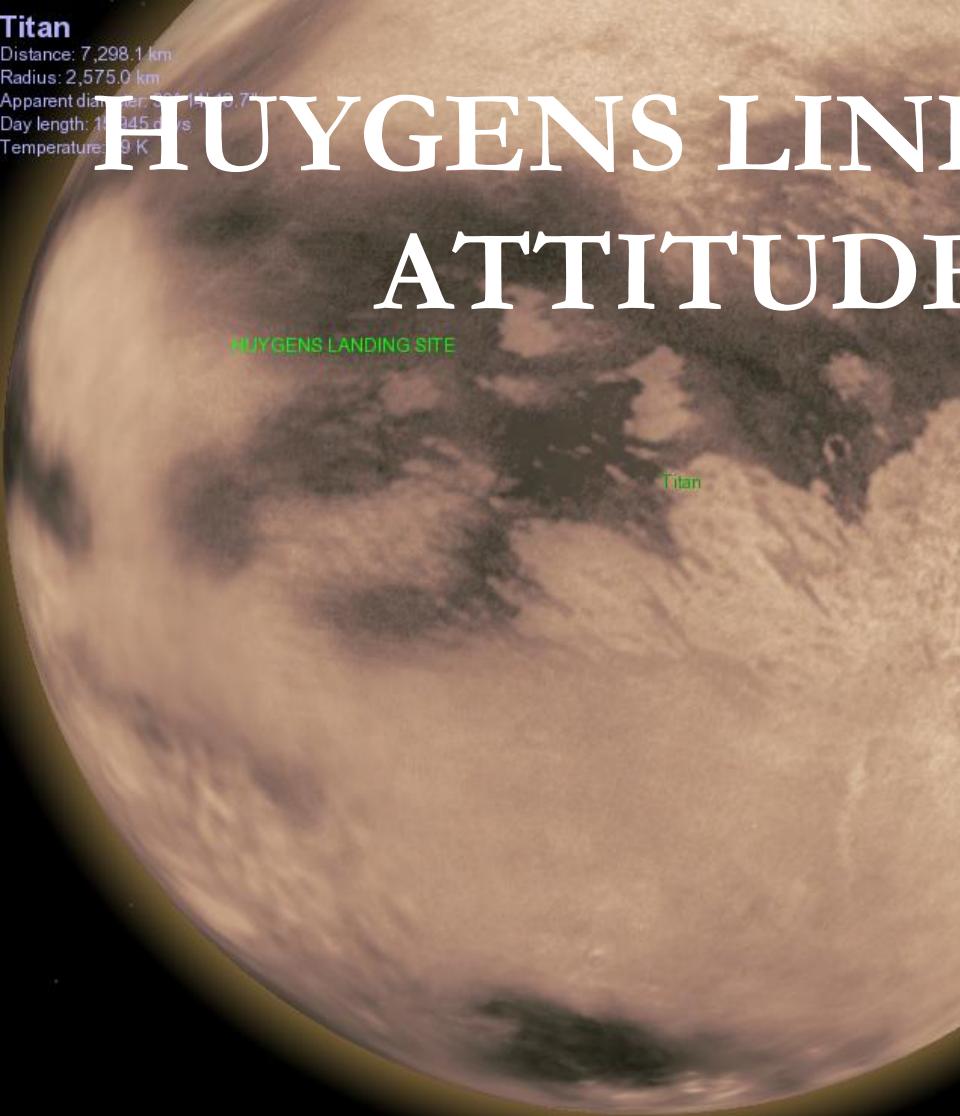
Apparent diameter: 0.7°

Day length: 16.945 days

Temperature: 9 K

Real time

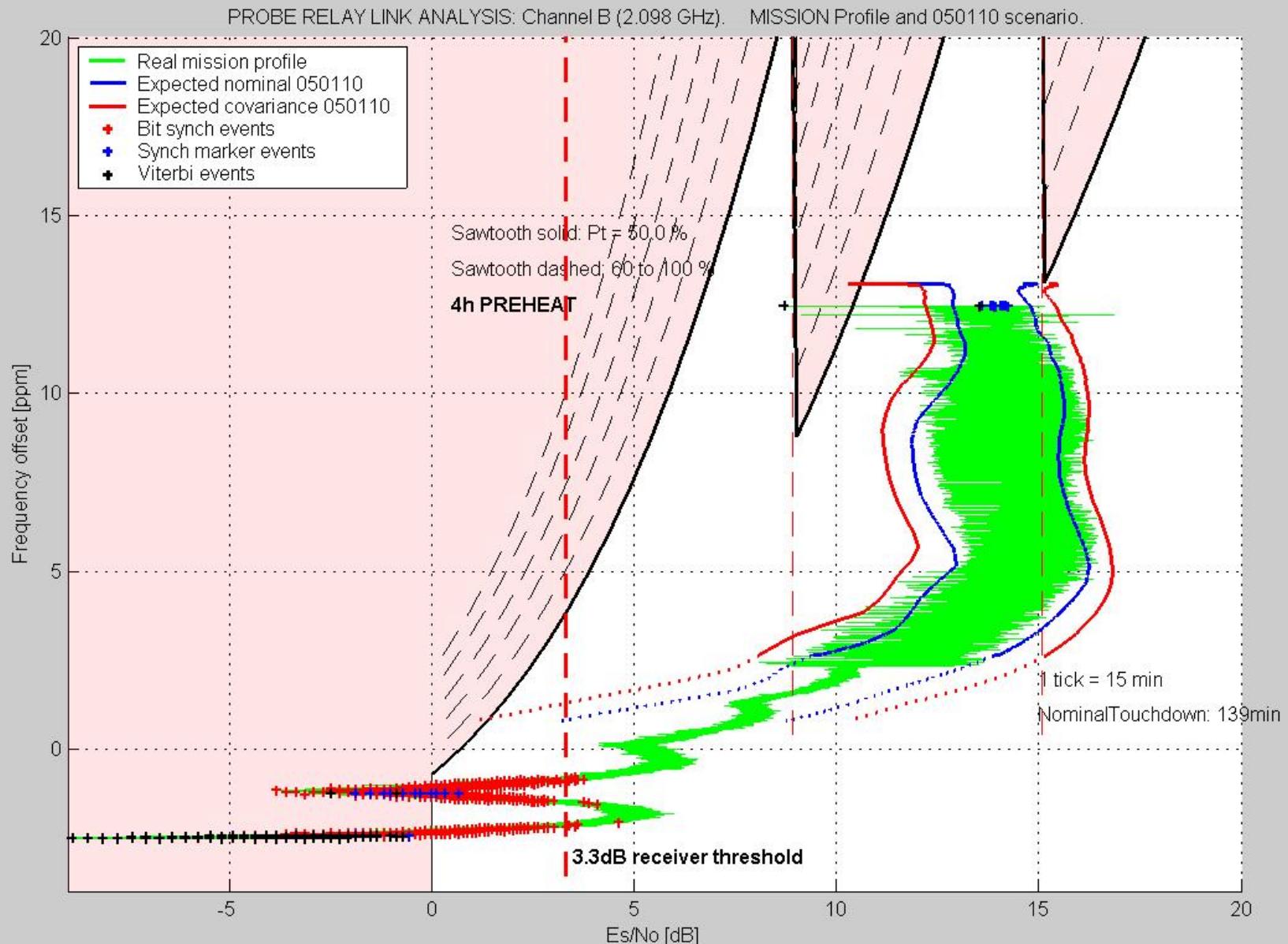
HUYGENS LINK ANALYSIS and ATTITUDE ASPECTS



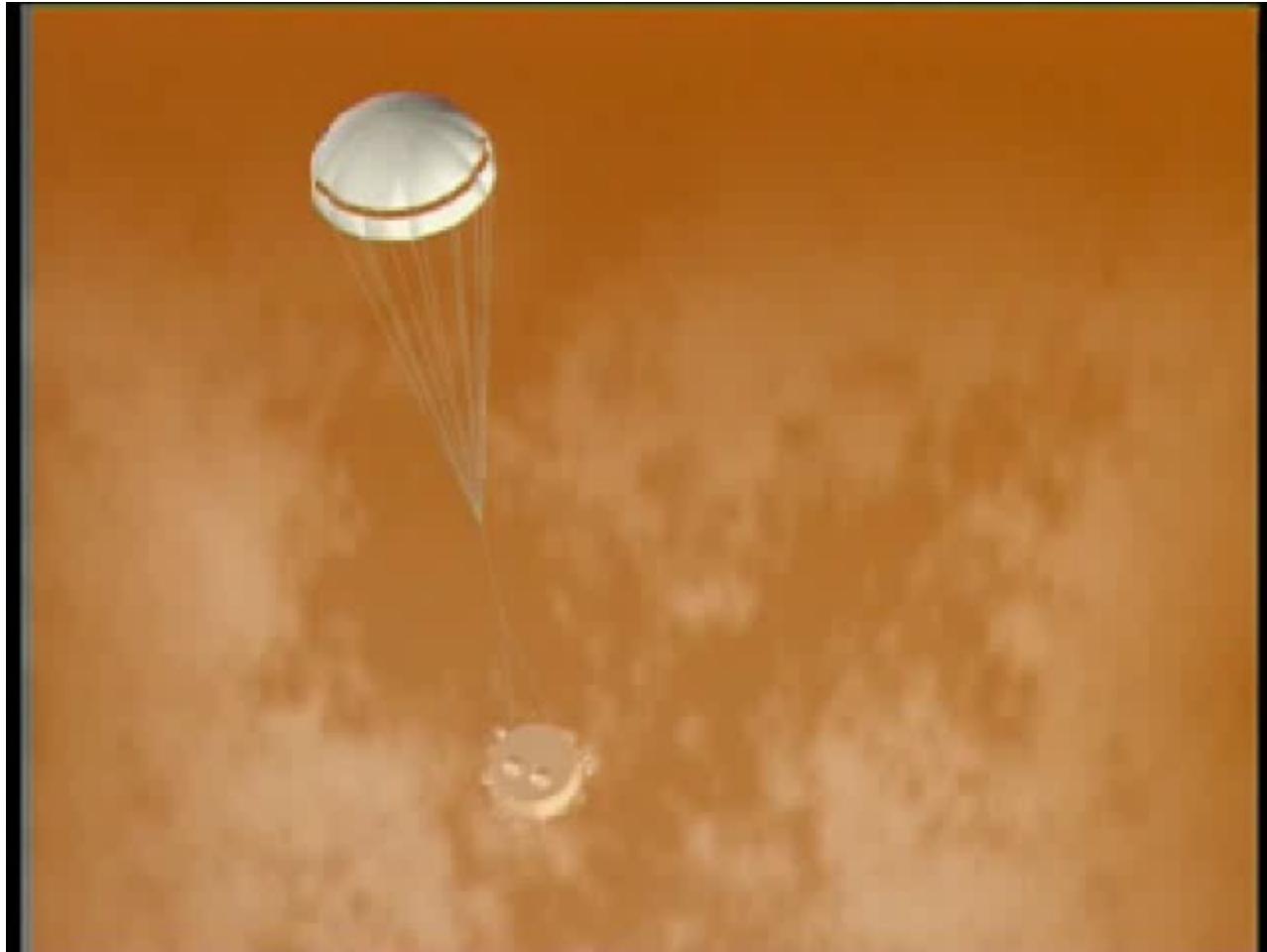
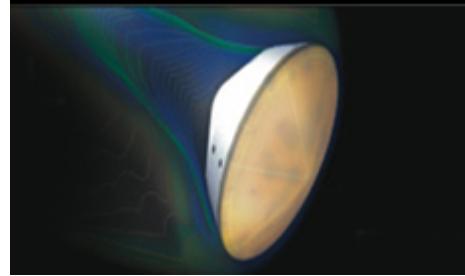
Miguel Perez PST, ESTEC, ESA
28 FEB 2005, Firenze, HSWT#29



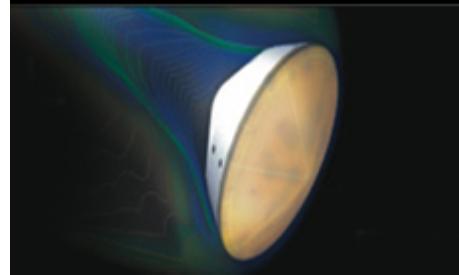
FINGER PLOT profile: reconstructed



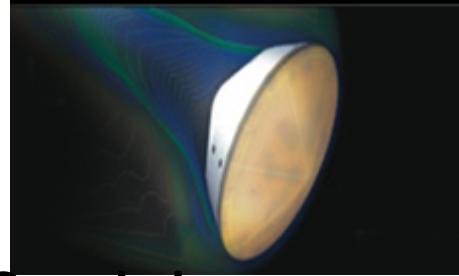
Back to the Future (1)



Back to the Future (2)



Conclusion



- It was a real privilege to work for so long on Cassini-Huygens. Great adventure with great teams.
- Many unique moments to remember for ever
- Huygens is a unique source of information to preserve.
 - Step 1 at Huygens legacy conference held in Barcelona in January 2010 (5th anniversary of the landing).
<http://vimeo.com/channels/huygenscelebration>
 - Step 2: Long-term knowledge preservation, a project that deserves to be brought to conclusionin time for TiME.